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TABLE 6.2
Drainage class definitions for soils in forested wetlands in the Coastal Plain of the southern United States (modified from Collins 1982).

Well drained — Sloping to rolling topography, with little or no run-off received from adjacent areas. Surface water may perch for short periods. Bright colors, and mottling, if present, occurs as few, faint, or distinct mottles at depth. Depth to permanent water table is greater than 2 m (6 ft). Soil has adequate moisture for plant growth, and wetness during the growing season does not limit plant growth.

Moderately well drained — Gently sloping to rolling topography but with low gradient and generally lower elevation; some seepage from adjacent areas. Soil absorbs much of the water it receives. Groundwater, if present, seldom rises above 50 cm (20 in) below the soil surface. May have subsoil horizon with slow permeability, and this horizon may impede internal drainage. Perched water table sometimes occurs. Soil properties such that moisture retention is generally adequate for plant growth. Some evidence of moisture accumulation or water table fluctuation within 75 cm (30 in) of the surface. Mottling occurs at depths greater than 50 cm (20 in), and gleying, if present, is 1 m (3 ft) or deeper. Subsoil has some gray mottles in pale-red and yellowish-grey subsoil matrix.

Somewhat poorly drained — Relatively flat land. Receives and absorbs both surface run-off and seepage from adjacent land or has a seasonally high ground-water table, or both. Sometimes has water standing on the surface. Surface soil usually has moderate to rapid permeability but is often underlain by layer with slow permeability; perched water table common. Mottling and gleying present in the surface 25 to 75 cm (10 to 30 in). Subsoil matrix yellowish-gray with pale red and strong brown mottles.

Poorly drained — Generally flat land or land concave in cross section. Ground water table, if present, generally high throughout the season; land often has water standing on the surface. Receives surface run-off and seepage from adjacent land. May be subject to flooding. Many poorly drained soils have fine-textured horizons with slow permeability within 50 cm (20 in) of the surface that seriously restrict internal drainage and may cause ponding or perched water tables. Mottling and gleying are quite pronounced even in the surface 50 cm (20 in) of the profile.

Very poorly drained — Ponded areas and depressions, or low areas subject to frequent flooding. Surface soil colors are black to dark-gray and gleying occurs within 25 cm (10 in) of the surface.

Runoff is the movement of precipitation water across the soil surface. In floodplain soils, a related term is sheetflow for the movement of water across the surface. Infiltration is the entry of water into the soil at its surface. Hydraulic conductivity is the rate of movement of water within a soil and varies depending on soil moisture status (saturated or unsaturated conditions). Hydraulic conductivity can refer either to horizontal or to vertical movement. Soil drainage class is an important if somewhat vague concept; it refers to the removal of water from the soil, which affects the degree and duration of wetness. While seven drainage classes are recognized, only five are relevant to discussion of forested wetlands. Drainage classes for Coastal Plain forested wetland soils are defined in Table 6.2.

The wetland classification created by Cowardin et al. (1979) introduced the term hydric soil. An interagency National Technical Committee for Hydric Soils determines the criteria for classifying soils as hydric, publishes a list of hydric soils and their taxonomic classification (SCS 1991), and provides descriptions of field indicators (NRCS 1995a). The presence of hydric soils is one of three indicators used to define jurisdictional wetlands which are subject to federal and state regulation (see Chapter 3).

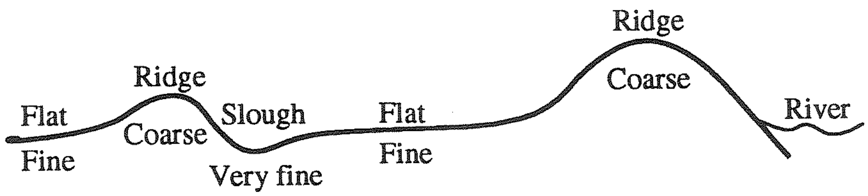

FIGURE 6.2 Floodplain soil texture variation.

horizons with >20 cm (8 in) thickness of organic soil material (see Table 6.4). Organic pans or spodic horizons can also form in sandy soils when organic matter, Fe, and aluminum (Al) move downward through surface horizons and accumulate in the zone of a fluctuating water table. Spodic horizons are most frequently observed 30 to 75 cm (12 to 30 in) below the soil surface and are relatively impervious to water. Wet spodic soils are characterized by dark surface horizons with high organic matter content and leached, dull gray horizons between the surface horizons and the spodic horizon (Brasfield et al. 1983). Spodosols are common features of pine flatwoods which have developed on thick sand beds deposited by coastal waters along former shorelines (Stout and Marion 1993). Seasonally saturated soils and seasonal flooding are characteristic of pine flatwood forests.

Mineral soils also predominate in riverine forests, but levels of organic matter are usually higher in these soils than in upland forests because productivity is high and because decomposition is inhibited periodically when riverine soils are flooded and anaerobic (Wharton et al. 1982). However, in contrast to water movement in wetlands that are isolated from lateral water flow, floodplain water movement is dominated by strong lateral fluxes which provide import and export of organic matter and maintain aerated soil conditions that promote decomposition at sufficient levels to minimize accumulation of organic matter.

Riverine forest soils are often weakly developed and classified as Entisols or Inceptisols because they are relatively recent in origin and are exposed to fluvial erosion and deposition. These processes strongly influence soil textural patterns, particularly in large floodplains which have heterogeneous topography (Figure 6.2). Localized ridges that form along current or former river banks in large floodplains have coarse-textured soils that contain large proportions of sand and silt because these areas have or formerly had rapidly moving floodwaters which deposit heavier sediments. Relatively low-lying backwater flats and former river channels or sloughs retain floodwater longer and are characterized by deposition of fine-textured soils that contain much clay. Resultant gradients in soil texture within floodplain forests influence soil aeration, porosity, permeability, structure, organic matter content, nutrient content, and ultimately vegetative composition.

Physical and Chemical Properties of Wetland Soils

Organic and mineral wetland soils can be distinguished by numerous properties (Table 6.5). Organic soils develop from organic sediments that originate within the ecosystem through accretion of organic matter, whereas mineral wetland soils are

Reduction of Fe and Mn leads to development of soil color that is often indicative of hydric soil status. Many mineral soils develop gray-green or gray-blue coloration (gleying) as a result of the chemical reduction of Fe. If oxidized zones occur within a gleyed soil matrix, oxidized Fe, oxidized Mn, or both will cause red-brown or black mottles. Gleying and mottle formation are controlled by redox potential, availability of organic substrates for microbial activity, and sufficient soil temperature to promote microbial activity. Sulfur transformations are important because hydrogen sulfide (H_2S), which can form under reduced conditions, can be toxic to plants and microbes. However, sulfides often combine with Fe_2^+ or Mn_2^+ to form nontoxic insoluble ferrous or manganous sulfides.

Phosphorus, too, is important in the chemistry of forested wetlands. Unlike N, it does not occur in a gaseous phase and is not altered directly by changes in redox potential. Phosphorus occurs in both organic and inorganic forms and is either soluble or insoluble depending on its associated compounds and the redox conditions of the wetland soil. Mineral wetland soils are characterized by a predominance of inorganic P attached to mineral soil sediments, whereas organic wetland soils have a predominance of organic P immobilized in organic matter. Phosphorus is indirectly influenced by changes in redox potential, becoming more soluble under reduced conditions through the hydrolysis and reduction of ferrous, aluminum, or calcium phosphates to more soluble compounds. The resultant soluble inorganic P occurs as orthophosphate (PO_4^{-3}, HPO_4^{-2}, or $H_2PO_4^-$). Under aerobic conditions, P precipitates as insoluble Fe, Al, or Ca phosphates. Phosphorus additions to riparian and floodplain forests often occur through deposition of clay particles in floodwater sediment. These adsorb the negatively charged phosphates.

The redox potential at which soil components become electron acceptors is affected by pH. This relationship can be demonstrated by pH-redox stability diagrams (Bohn et al. 1985). Basic soils require lower redox potentials for reduction of soil components (Bohn et al. 1985). Generally, pH tends towards neutrality in reduced soils. Thus, pH will increase in an acid soil undergoing reduction but decrease in an alkaline soil. These changes are controlled by soil Fe and organic matter content. In acid soil, reduction of Fe consumes H^+ ions and increases pH. In alkaline soils, production of CO_2 is greater than reduction of Fe and pH decreases (Bohn et al. 1985). Wetland soils have a wide range of pH; organic soils are often acidic, and mineral soils are often closer to neutral or alkaline (Mitsch and Gosselink 1993).

Hydrologic Classification of Wetlands

All wetlands can be classified as riverine, basin, or fringe wetlands, based upon their hydrology (Kangas 1990, Lugo 1990b). Some common terms for forested wetlands in the South are given in Table 6.6 and grouped by these classes. Many of these terms refer to wetlands defined by their distinctive vegetation and landscape position. Some of these forested wetland communities are described more fully in other chapters.

recent marine terraces. Inland, distinctive Vertisols with shrink and swell properties are developed on a band of outcropping Selma Chalk. This band is known locally as the Black Belt or Black Prairie and extends across central Alabama and northeastern Mississippi. Other blackland belts occur in Texas, Louisiana, and Arkansas.

The West Gulf Coastal Plain Section is similar to the East Gulf Coastal Plain Section, although it is considerably wider and more faulted. The section's major rivers have very extensive drainage basins and have formed large deltaic deposits. In the West Gulf, soils are more neutral to alkaline than in the East Gulf and have mixed and smectite mineralogies.

SOILS OF RIVERINE WETLANDS

River systems supporting riverine wetlands abound in the South. Floodplain widths vary from several km to narrow strips of vegetation (Sharitz and Mitsch 1993). Alluvial (redwater) rivers originate in the mountains and the Piedmont. These rivers have many tributaries and relatively large watersheds, and so have sustained high flows in the winter and spring. Blackwater rivers and their tributaries originate entirely in the Coastal Plain. They receive most of their water from local precipitation, and baseflow (groundwater seepage) is a large component of low flows. Blackwater rivers are often tributaries of alluvial rivers. High water levels in alluvial rivers can impede discharge from, and cause flooding of, blackwater rivers. Blackwater rivers get their name from their dark color, a legacy of humic (organic) substances flushed from swamps. Because of their low gradient, blackwater systems tend to have less sediment transport and deposition than alluvial rivers, and hence have less well-developed floodplain features.

We now recognize that the present southern floodplains owe at least some of their features to Pleistocene glaciation and periglacial climate (Wharton et al. 1982). Solifluction, the slow downslope movement of saturated soil masses, during the Pleistocene caused Piedmont valley filling and subsequent incision of Piedmont rivers. The rising and lowering of sea level during interglacial and glacial periods caused changes in gradients of rivers originating in the mountains and Piedmont. One consequence is that most rivers presently occupy floodplains too large to have been formed by their present discharge volume and meander dimensions (Wharton et al. 1982). Another consequence is the occurrence of relict floodplain features. There are two or more relict terraces along many alluvial rivers and relict braided channels in the Mississippi River system. Post-glacial sea-level rise has drowned the mouths of Atlantic Coastal Plain rivers such as the Roanoke and Chowan and caused the formation of Holocene meander belts in the Mississippi system (Saucier 1994).

Although major rivers were covered by the sea in their lower reaches as a result of sea-level rise, their tributaries often have extensive floodplains. Examples are the James, Chowan, and Roanoke Rivers in Virginia and northern North Carolina and the Escambia and Choctawhatchee Rivers in Florida (Wharton et al. 1982). Rivers with narrow floodplains include the Pamlico and Neuse Rivers in North Carolina.

TABLE 6.7
Generalized soil properties of some major southern forested wetland types.

Location/Landform	pH	Organic Matter (%)	Clay (%)	Phosphorus (mg/kg)
Alluvial Rivers in the Atlantic Coastal Plain[1]				
Swamp	5.3	35.0	45	10
Low flat	5.4	4.4	44	10
High flat	6.2	2.5	35	6
Ridge	6.2	3.0	18	4
Blackwater Rivers in the Atlantic Coastal Plain[1]				
Swamp	5.5	17.1	19	11
Flat	5.1	7.9	12	10
Red and Arkansas Rivers in the Gulf Coastal Plain[2]				
Mixed bottom	4.6	2.4	50	16
Red river bottom	5.8	3.7	59	19
Terrace	4.6	2.0	18	18
Minor Bottoms in the Gulf Coastal Plain[3]				
Coastal plain alluvium	5.0	1.0	12	6
Blackland alluvium	4.8	1.9	32	12
Blackland alluvium, acidic	4.0	2.1	35	4
Blackland alluvium, calcareous	6.0	2.5	40	20
Mississippi River Alluvium[4]				
Recent levee	6.8	2.5	38	20
Old levee	5.1	2.2	40	22
Slackwater	5.6	2.4	60	18
Loess Bluff Bottoms in the Gulf Coastal Plain[1]				
Acid	5.2	1.8	22	14
Neutral	6.0	1.2	11	11

[1] Kellison et al. 1982, Wharton et al. 1982, Daniels et al. 1984
[2] Broadfoot 1964, 1976
[3] Broadfoot 1964, 1976, Southern Forest Soils Council 1990, Alabama Forestry Planning Committee 1993
[4] Broadfoot 1964, 1976, Brown et al. no date, Patrick et al. 1981

are typical, and these are formed in alluvium mainly derived from the Western Plains. More alkaline soils occur in the floodplains of the Red River, and more acid soils in the Arkansas River bottoms (Table 6.7). Distinct older terraces are found in these systems, and soils of these terraces have coarser textures than those of the active floodplain. Alfisols, Mollisols, and Vertisols are common. Common soils in these systems include Portland, Perry, Buxin, and Roebuck in the bottom and Asa, Morse, and Gore on terraces.

Minor Bottoms

Minor bottoms have floodplains from less than 1 km (0.6 mi) to several km in width, and their streams flood frequently but for short duration (Hodges, pers. comm.).

with the Histosols of pocosins. A cross section of a typical pocosin would show the Portsmouth series (mineral soil) grading into the Ponzer and Dare series (organic soils) as the thickness of the organic layer increased. Other Histosols in the peat or muck areas of North Carolina include Belhaven, Scuppernong, Mattamuskeet, Croatan, Pungo, and Pamlico (Daniels et al. 1984).

Flatwoods and Savannas

True flatwoods in south Georgia and north Florida occur on Spodosols (predominantly Haplaquods), poorly to somewhat poorly drained soils developed in coarse-textured sediments (Abrahamson and Hartnett 1990, Morris and Campbell 1991). More widespread are the savannas, which are also known as wet mineral flats or pitcher plant (*Sarracenia* spp.) flats. These areas are found in both the Atlantic and Gulf Coastal Plains. Savannas are found on finer-textured soils, usually Ultisols (Paleaquults and Haplaquults) and Inceptisols (Humaquepts). They developed in slack-water deposits and are poorly to very poorly drained. Many of these areas are now in pine plantations. Typical soils include Portsmouth, Bladen, Rutlege, Plummer, Mascotte, and Sapelo series.

Cypress Domes

Cypress domes or ponds are isolated depressions filled with acid, peaty, mineral soils. In Florida, they often occur within pine flatwoods (Ewel 1990b). A related feature, the cypress strand, has some flow and an outlet, and thus is a riverine wetland, although the difference between domes and strands is problematic. Cypress domes are moist or inundated for long periods but dry out at the surface, especially in droughty summers. They may have clay pans or lenses beneath their sandy surface soils or occur in depressions in marl and limestone bedrock (Coultas and Deuver 1984, Brown et al. 1990, Ewel 1990b).

Carolina Bays

Carolina bays are curious, ovate depressions that occur in the Coastal Plain (Richardson and Gibbons 1993), most abundantly in the Middle Coastal Plain. They are seldom found in areas of clay soils or where silt content is high in North Carolina (Daniels et al. 1984), but many South Carolina bays have clayey soils of the Coxville, Rembert, or McColl series (McKee, pers. comm.). The longer axes of these features trend from northwest to southeast. On the northwest, the transition to the surrounding upland is gradual, but around the remainder of the oval, a distinct rim is common. The soil of the rim is sandy and may rise 1 to 3 m (3 to 10 ft) above the bay floor. The bay floor may have organic or wet mineral soils (Daniels et al. 1984).

Soils of Carolina bays are organic (Croatan, Mattamuskeet, and Pamlico) or mineral in the interior (Byars, Pantego, Torhunta, Coxville, McColl, and Rains). Soils of the sandy rim are well to moderately well drained series such as Norfolk, Bonneau, Wakulla, Lakeland, or Chipley.